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THE UNIVERSITY OF ALBERTA

A COMPARATIVE STUDY OF CLASSROOM METHODS IN THE TEACHING OF CHEMISTRY

A DISSERTATION
SUBMITTED TO THE GRADUATE FACULTY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF ARTS

DEPARTMENT OF EDUCATION

BY
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EDMONTON, ALBERTA
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CHAPTER I

SCOPE AND PURPOSE OF INVESTIGATION

The scope of this investigation covered a year's work in Chemistry I as carried out in the Strathcona High School, Edmonton, during the year 1938 - 1939.

Three Grade XI classes were involved in the experiment. The students, numbering one hundred and two in all, were beginners in Chemistry, with the exception of six who were repeating the course.

The three classes were unselected as to number, quality and attainment. Exigencies of school organization made it impossible to make any preliminary selection or to attempt to balance the classes in these regards. The students were at liberty to select the classes which they attended and, in making their selection, timetable considerations were paramount. However, during the first week they were advised as to the nature of the experiment and were invited to arrange their programs as far as possible to suit their own preferences as to the type of instruction offered.

The fortuitous selection of the three classes did not result in their being greatly unbalanced however, except, perhaps, as to numbers. Class I numbered 40 students at the beginning of the year, Class II numbered 34, and Class III numbered 30. This divergence was compensated for to some degree by making the first and largest class the subject for the most mechanical type of instruction, whilst the smallest class was instructed on the more individualized and less formal technique.

As to average ability and scientific attainment, as measured at the beginning of the year, the three classes were found to be closely balanced.

I.Q.'s were taken from the school files and were on the basis of the Smith-Willis test. In most cases these had been administered three or four years previously. These I.Q.'s are listed in Table I. They are not complete, there being about six in each class for whom no records were available. The averages are as follows:- Class I - 104.6, Class II - 104.6, and Class III - 104.8, and the medians, Class I - 104, Class II - 103 and Class III - 103. None of the individuals not listed were markedly superior or inferior students and there was no reason to suppose that their inclusion would influence these averages by more than one or two points at the most. Incidently it will be noticed that these I.Q.'s are rather low, for according to Terman the average for grades XI - XII is 111-114.

The students were also tested as to scientific attainment on the basis of the Vocabulary test devised by Armstrong (Alberta, 1937.) This test which aims to guage the scientific attainment of the student by measuring his science vocabulary also gave fairly uniform results. (Table 2.) The average scores were, Class I -59.8, Class II -64.2, Class III - 65.0. The general inference would seem to be that the three classes were rather well balanced with the possibility of a slight inferiority in the case of Class I.

TABLE I

INTELLIGENCE QUOTIENTS - SMITH-WILLIS TESTS.

	Class I.	Class II.	Class III.
	80	90	90
	82	93	90
	85	95	91
	90	95	94
	91	95	97
	93	95	98
	93	95	99
	95	95	100
	95	96	100
	96	97	100
	97	100	101
	99	101	102
	100	101	102
	101	103	102
	102	103	104
	104	105	105
	104	106	108
	105	106	109
	106	106	109
	107	109	109
	108	115	109
	109	115	112
	111	117	112
	112	119	113
	116	122	113
	120	124	116
	120	128	117
	121		132
	122		
	125		
	128		
	134		
Totals	3351	2826	2934
No. =	32	27	28
Average	105.0	104.6	104.8
Medians	104.0	103.0	103.0

I.Q.'s not available for eight students in Class 1, four in Class II, and two in Class I. None of these showed evidence of deviating greatly from the norm however and it is doubtful whether their inclusion would influence these averages by more than one point either way.

TABLE II.

SCORES ON SCIENCE VOCABULARY TEST - BY CLASSES.

	Class I	Class II	Class III
	40	44	39
	39	42	39
	38	40	39
	38	39	39
	37	39	38
	37	38	37
	36	38	37
	36	37	37
	35	35	37
	34	35	37
	34	34	36
	34	33	34
	34	33	34
	32	32	33
	32	31	33
	31	31	33
	31	31	33
	31	30	32
	30	30	31
	30	30	31
	30	30	30
	30	30	29
	30	28	29
	29	27	29
	29	27	28
	29	27	28
	28	27	28
	28	25	26
	27	25	25
	26	24	24
	26	24	23
	25		
	25		
	24		
	24		
	22		
	21		
	20		
	20		
	15		
Totals	1197	996	1008
No. =	40	31	31
Median	30	31	33
Average	29.9	32.1	32.5
Average %	59.8	64.2	65.0

General Aim.

The intention of the investigation was to compare the results of using different techniques in the teaching of the same chemistry course. The general idea was to have a gradation of techniques. In Class I a purely stereotyped, mechanical method of presentation was to be used. In Class II the more conventional lecture-recitation procedure was planned and in Class III the unit system based on the type of technique developed by Professor Henry C. Morrison[1] of the University of Chicago was used.

It was also intended to organize laboratory work along the same general lines. Class I was to do experiments individually, using typewritten instructions. Class II was to have all experiments demonstrated by the teacher and Class III was to have access to laboratory material as their necessities and interests dictated.

Ten tests were planned corresponding to the ten major units into which the course was divided and which formed the basis for instruction in Class III, and all three classes were to write these tests.

The tests were to be objective and of the short answer or multiple response type.

Detailed Plan.

Class I. In this class a work book[2] as used by the Department of Education for its correspondence course in Chemistry I was made the basis of instruction. This work book consists of

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[1] "The Practice of Teaching in the Secondary School"

[2] See Sample Lesson. Appendixll.

eighteen lessons covering the material in the authorized text; viz., Black and Connant's "New Practical Chemistry." The student is directed in the work book to read certain prescribed sections of the text and then to write answers to a series of study questions, for which answers blanks are provided. At the end of each lesson there are twenty "Examination questions" which he answers using the text for reference. In conducting this class provision was made for an occasional recitation period in which difficulties were taken up and a check made on the students' work with a view to seeing that the blanks were systematically filled out. The students were encouraged to proceed with the work as fast as they cared, provided they kept within the limits of the particular unit on which Class III was engaged. This was necessary in order that all three classes should write the tests simultaneously. Help was given to individual students as requested but an effort was made to restrict this to assisting the student to locate information in the text book or other source. Only on occasions when the class was obviously unable to make progress unaided was there any attempt at formal teaching in this class.

The laboratory work of this class did not follow strictly the procedure planned. An attempt was made to carry out experiments with typewritten (mimeographed) instructions only, but the students were found to be so inexperienced in the handling of apparatus that a great deal of explanation and verbal advice was found necessary. Also, in some of the more difficult manipulations as in the preparation of certain gases, a demon-

stration by the teacher was deemed preferable. Towards the end of the year, however, the mimeographed sheets of instructions were used, the students having learned something of laboratory procedure in the meantime.

Class II. In this class the customary lecture-recitation procedure was followed. The material covered in several sections of the text was presented to the class by verbal instruction. Experiments were demonstrated by the teacher for the most part, although upon request by the students an opportunity to do individual work was afforded in the case of certain simpler experiments. The students were assisted in making notes. Occasionally these notes were dictated, but most of the time the student made summaries of the text material as directed. Each day's lesson started with a brief review of the preceding day's work.

Class III. For the third class the course was divided into ten topics or units. Each unit was developed according to the procedure advocated by Professor Morrison of Chicago, along the following lines:-

1. Pretest. A preliminary exploration of the students' present orientation in relation to the topic was first made. This usually took the form of a general discussion between the teacher and class. The students were encouraged to talk freely on the subject without attempting to restrict them to any set line of development. In one or two cases a short

written test was used as the basis of this preview.[1]

2. Presentation. The essential points of the topic were covered by the teacher in a direct twenty-to-thirty minutes discourse. According to Morrison there is in every teaching situation an "essential adaptation" which the student needs to make in his relation to the subject. An effort was made to isolate this essential adaptation and present it as the core of the lesson. During the last five or ten minutes of the period a review of these main points was written on the board. The following day a written test was conducted on the lesson. Those students who had acquired 85% or better were considered as having made the necessary adaptation. Although this 85% falls short of Morrison's "Mastery formula", according to which every student should achieve 100% mastery of the essential facts, it was found necessary to make this concession in order to cover the course in one year. These successful students were then assigned "assimilative material" which they studied by themselves as explained in the next step. The rest of the class were retaught the lesson, modifications in the procedure being made where necessary, and, the next day, tested again. This was continued until all the class had been brought up to the 85% standard. In most of the units three

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[1] "The Practice of Teaching in the Secondary Schools" -H. C. Morrison. P.82, 256, 267, etc.

or four teachings were usually found sufficient to achieve this, although in several of the units there was a small residuum of the class for whom the 85% mark seemed beyond their capacities no matter how many times the lesson was repeated.

Assimilation. This phase of the work consisted of individual study of any relevant material available. The students were assigned sections of the text to read with occasional references in other texts, magazines or newspaper clippings. For the first unit they were guided in their methods of individual study but after that they were left mainly to their own devices. They were invited to perform individual experiments as they came to them in the course of their study. However, their own habits of restraint in the classroom and the obvious advantage to the teacher of having the same experiments performed by the whole class simultaneously, worked against this informality and generally speaking, the laboratory work proceeded along formal lines. Some of the more difficult experiments were demonstrated by a group of students for the benefit of the rest of the class. Answers to questions in the text were written out but no formal notes were made at this stage, although rough notes of all experimental work were kept.

The Unit Test. When this assimilative work had been completed by the whole class the unit test was written. These were mimeographed short-answer tests in which blanks were to be filled in by the student. Copies of these are included under each unit. Generally speaking these tests

consisted of from ten to fifteen questions, each question having from four to six blanks. They formed the basis of comparison of the three classes at the conclusion of each test. In this class, however, the work did not end there. Each student was required to restudy the assimilative work in respect to those questions in which he had failed to score at least 75%, i.e. three out of four, four out of five or five out of six of the blanks correct as the case might be. A record of each question for each student was kept and the complete mastery of the unit was required as the ideal of attainment.

Organization. The next step in procedure for Class III was the organization and representation of the work. In class discussion suitable headings were selected and the students were then required to write a report on the unit with a complete account of all experimental work done and information accumulated.

Recall. The final stage in the Morrison technique is the oral re-presentation of the work. A number of students were selected to give oral talks on different aspects of the topic. In order to avoid monotomy of repetition these students were encouraged to seek out still further sources of information and to present interesting talks for the benefit of the class.

The one difficulty here was the time factor. In order to keep the work in line with the other two classes it was impossible to devote more than one period to this interesting phase of the work and in some cases it had to

be eliminated altogether. Also, the written reports had to be assigned for homework for the same reason.

CHAPTER II

UNIT I - CHEMICAL CHANGE AND CHEMICAL COMPOUNDS

Procedure.

Class I. Lesson II of the work book was completed with written answers to the twenty "examination" questions as directed. (See pp. 7-9 of work book.) Two experiments were performed using written instructions.

Class II. Chapters II and III of the text, Black and Connant's "New Practical Chemistry" was covered by the teacher in a series of lessons spread over two weeks. The lessons commenced with a brief review of the previous day's work and proceeded with an oral discourse by the teacher, with occasional questions. Several simple experiments were demonstrated by the teacher and the students summarized the text material and wrote notes of experiments under direction. The same problems assigned to class I were taken up in class and answers written for them.

Class III. A pretest, which consisted of a class discussion of compounds, elements, substances, materials and chemical and physical changes was held. There was evidence from this that the class had a good knowledge of the unit in advance.

The presentation consisted of definitions of certain technical terms (element, compound substance etc.) and two of the fundamental laws of chemical combination. Only two teachings were required for the majority of the class.

Assimilative material included Chapters II and III of Black and Connant's text, Chapter III of Cornish's Elementary Chemistry, Experiments I and 2 of "New Laboratory Experiments" by Black, the latter being performed by the students themselves, and problems from the text, as in the other two classes. The unit test was then administered to all three classes with results as tabulated below.

TABLE III

RESULTS OF TEST UNIT I.

Max. Mark = 15	Class I		Class II		Class III	
	15	10	14	10	13	11
	13	10	14	10	13	10
	13	10	13	10	12	10
	13	10	13	9	12	10
	12	10	13	9	12	10
	12	10	13	8	12	10
	12	10	13	8	12	10
	12	9	13	8	12	10
	12	9	12	7	12	9
	12	9	12	6	12	
	12	9	12		12	
	12	9	12		11	
	12	9	12		11	
	11	9	11		11	
	11	9	11		11	
	11	8	11		11	
	11	8	10		11	
	11	7	10		11	
	11	5	10		11	
	11		10		11	
	11		10		11	
Totals		420		334		334
N -		40		31		30
Medians		11.0		11.0		11.0
Averages		10.5		10.8		11.1
Averages %		70.0		72.0		74.2

Class III continued to study the unit until mastery had been attained. This work concluded with a written report and one period in which seven students presented oral talks on phases of the work.

Comment. The averages show a slight superiority in the case of class III. The median marks are the same for the three classes. In general the work presented no great difficulty to any class.

The slight~~ly~~ margin of superiority indicated by Class III in this test was doubtless due to the repeated teaching of essential facts, although the unit test included much of the assimilative material as well.

Class I worked enthusiastically on the work books although apparently they retained slightly less than the others.

Class II showed the least enthusiasm of the three classes. This class was being taught in the usual routine and, apparently, lacked the stimulus of a new method of approach to centre their attention on the subject quickly. There was a tendency for them to be preoccupied with the disciplinary situation and to explore the possibilities in this direction before they finally turned their attention to the learning situation. The comparatively poor showing of this class in the second and third units, as will be shown, may have been due to the persistence of this situation for the first few weeks of the course. This will be discussed more fully in the general conclusion.

Unit Test, Unit #I - Chemical Change and Chemical Compounds.

In the space provided at the end of each question place the number of the word or phrase which completes the statement most satisfactorily.

1. A change of state is (I) permanent, (2) reversible, (3) temporary. ( )

2. The most important result of a chemical change is (I) heat is produced, (2) matter is destroyed, (3) a new substance is formed. ( )

3. In running an automobile the gasoline undergoes (I) a chemical change, (2) a physical change, (3) a combination of physical and chemical changes. ( )

4. We recognize substance by their (I) appearance, (2) properties, (3) texture. ( )

5. When iron filings and sulfur are heated together we obtain (i) a mixture, (2) iron sulfide, (3) charcoal. ( )

6. The Law of Conservation of Weight says (I) the total weight of the substances formed in a chemical reaction is the same as the weight of the substances that enter into the reaction, (2) the proportion of the elements in a compound is always the same, (3) you cannot destroy matter by burning it. ( )

7. Substances are distinguished from materials in that they are (I) heterogeneous, (2) endogenous, (3) homogeneous. ( )

8. Water is said to be a compound because (I) it is a mixture of hydrogen and oxygen, (2) it has a very complex structure, (3) it may be broken down into two elements. ( )

9. Red oxide of mercury is (I) a compound, (2) a mixture of mercury and oxygen, (3) a metallic element. ( )

10. When two elements combine to form a compound the process is called (I) synthesis, (2) oxidation, (3) decomposition. ( )

11. The fact that copper sulfide always contains 66.7% of copper and 33.3% of sulfur illustrates the law of (I) Conservation of matter, (2) Multiple Proportions, (3) Definite proportions. ( )

12. Brass is (I) an element, (2) an alloy, (3) a compound of zinc and copper. ( )

13. A good example of a non-metal is (I) carbon dioxide, (2) coal, (3) phosphorus. ( )

14. When clear solutions of sodium chloride and silver nitrate are mixed we know that a chemical reaction has taken place because (I) heat is given out, (2) a precipitate appears, (3) the weight remains the same. ( )

15. The best way to tell if a given sample of water is pure is (1) taste it, (2) evaporate and see if there is a residue, (3) see if it freezes at 0 degrees Centigrade. ( )

CHAPTER III.

UNIT II - OXIDATION AND COMBUSTION.

Procedure.

Class I. Lesson 3 of the work book was completed. Two experiments, the instructions for which were mimeographed, were performed by the class without any supplementary instructions by the teacher. Experiment 4 was conducted in a similar way except that the instructions were written on the board. Experiment 5, (Black's "New Practical Experiments") performed by a group of four students and demonstrated to the rest of the class.

Class II. Chapter IV of Black and Connant's text was taught by the teacher. The same laboratory procedure was used as in class I only the written instructions were amplified by verbal instruction by the teacher. Experiment 5 was demonstrated by the teacher.

Class III. A preliminary discussion with the class covered the meaning and significance of combustion, sources of oxygen and possible explanations of burning. The essential idea of combustion as a process involving union of a substance with oxygen, together with methods of preparing oxygen, the use of a catalyst etc. were then presented in a short class period. This was tested and retaught until at least 85% was retained by each member of the class.

The assimilative material included Chapter lV, Black and Connant's text, Chapter III Cornish's chemistry and the same experiments as in Class I only using a laboratory manual.

The unit test (Page 18) was then administered and repeated until mastery had been attained by the greater majority. A report was written and one period allowed for oral talks.

Unit Test. Unit II. Combustion and Oxidation.

In the following fill in the blanks with the most suitable words.

1. Oxygen is the most .... element in the atmosphere, since it combines with nearly all the other .... to form ....

2. .... is the most abundant element in the atmosphere, but .... is the most abundant in the earth's crust.

3. In 1774 .... prepared oxygen from .... In the laboratory we prepare oxygen by heating .... This is a substance used commercially for making ....

4. We can represent the change involved in the laboratory preparation of oxygen by the following equation: ....

5. To hasten this reaction we add .... This substance is said to be a .... It enables the oxygen to come off at a .... temperature. It is itself .... in the reaction.

6. We test for oxygen by its action on a .... The oxygen causes it to .... Oxygen .... better than air.

7. A substance which will not ordinarily burn in air but does so in oxygen is .... It changes to ....

8. Sulfur burns in oxygen with a .... flame. The gas left is called .... Similarly charcoal burns in oxygen to form ....

9. Chemists of the seventeenth century believed that all combustible substances contained a fire-stuff called .... This was lost when the substance burned leaving behind the .... Lavoisier showed this could

Unit II test continued.

(9) cont. not be so becaused many substances weigh .... after heating. This change in weight is due to the .... absorbed.

(10) In his twelve day's experiment Lavoisier heated some .... in a retort. He found some particles of .... in the retort. He concluded that a part of the .... had combined with the .... He called the inactive part of the air .... and the active part ....

(11) One element that will ignite spontaneously is .... This is because it has a .... ignition temperature. This temperature is reached when the element is gradually heated by a process of ....

(12) Water will extinguish a fire because it .... the burning material and also prevents .... from reaching it.

(13) Oxygen is used with .... to provide an intensely hot flame for .... metals. It is also used in hospitals for .... and in all cases where there is danger of ....

(14) .... is a more concentrated form of oxygen. At ordinary temperatures it is a much more powerful .... agent. In several European cities it is used to .... the .... It is an .... form of oxygen, and contains more ....

(15) An explosion is a chemical reaction in which .... undergo instantaneous ....

Total value - 50

TABLE IV

RESULTS OF TEST - UNIT II

Max. Mark - 50	Class 1.		Class II.		Class III.	
	46	34	47	33	49	35
	44	33	43	32	49	34
	43	33	43	32	49	34
	42	33	42	31	44	34
	42	33	41	31	43	32
	41	32	40	30	42	32
	40	32	39	28	42	32
	39	32	39	28	41	29
	39	30	38	26	41	28
	39	30	38	26	40	21
	38	29	38	25	40	20
	38	29	37	24	39	
	38	28	36	17	39	
	38	27	36	11	37	
	38	27	36		37	
	37	26	34		36	
	36	26	34		36	
	35	23	33		36	
	35				36	
	35	34				
Total	1344		1068		1107	
N -	39		32		30	
Average -	34.25		33.4		36.9	
Average % -	68.5		66.8		73.8	
Median -	35		34		36	

Comment. On the basis of the median mark Class III shows a superiority over the other two classes but the divirgence is not nearly so great as is shown by the average. This is due to the three 49's in Class III which raises the average mark considerably.

It will be noted that the poorest class was the one which received the most teaching as far as actual hours of

instruction were concerned. The reason was apparently due to poor attention displayed by this class compared to the other two - a factor probably related to the type of technique used. This point is discussed more fully in the final conclusions.

CHAPTER IV

UNIT 3 - HYDROGEN AND ITS OXIDES.

Procedure.

Class 1. Lessons 4 and 5 of the Work Book were completed and the "examination questions" as assigned in the work book were answered and discussed in class. Experiments 7, 8 and 14 of Black's "New Laboratory Experiments" were performed in small groups from instructions written on the board. Experiment 9, "Quantitative Composition of Water" was demonstrated by the teacher.

Class II. The material of Chapters V and VI, Black and Connant's text, was taught by the teacher. The same experimental work as for Class I was carried out, only with step by step explanation by the teacher. Notes and reports of experiments were required of the students.

Class III. A pretest consisting of a preliminary discussion of water and hydrogen in their various aspects was conducted. In a half-hour presentation the essential idea of hydrogen as a constituent of water and acids, methods of liberation of hydrogen from these sources, its recombination with oxygen and other elements was taught and retaught until each student attained 85% or better on a test.

Assimilative material included Chapters V and VI of Black and Connant's text, Chapter V of Cornish's Elementary Chemistry, the laboratory work as for the other classes, only with direct use of the Laboratory text, and experi-

ment 9 demonstrated by the teacher.

The unit test (page 23) was administered to each class. Class III restudied the work until mastery of the material was attained. A written report and oral work completed the unit for this class.

Unit Test. Unit #3 - Hydrogen and its Oxides.

Fill in the blanks below:-

1. The purest form of natural water is .... It is a naturally .... form of water. Spring water contains ...., but it is fit to drink if it is free from ....

2. We can tell water from any other colorless liquid by its action on .... which it turns.....

3. Hydrogen can be obtained from water by the action of .... or .... When these metals act on water they form ....and .... respectively. Steam can be decomposed by its action on.................

4. The best laboratory preparation of hydrogen is by the action of .... on .... Hydrogen is given off and ....is left.

5. Water is composed of hydrogen and oxygen in the proportion of ...., by volume, and .... by weight. To prove this by a synthetic process we use a .... and explode a mixture of the gases by connecting the terminals to an ....

6. If a lighted candle is thrust up into an inverted jar of hydrogen the gas .... and the candle .... This shows that hydrogen .... but does not ....

7. To show that hydrogen is a reducing agent we pass it over heated .... The products of this reaction are .... and .... To dry the hydrogen it is passed through a tube containing ....

8. Crisco is made by the process known as ...... In this process .... is passed into .... which are thus changed into ......

Unit Test #3 Continued.

8. contined.
There is an allotropic form of hydrogen known as .... When it is burned it forms ....

9. Water is a standard for measuring .... and .... It is also known as a ...... solvent. The substance dissolved is called the ....

10. City water supplies are purified by adding .... or .... In nature running water is purified by the action of ....

11. There are two oxides of ordinary hydrogen namely .... and .... The heavier of these contains .... as much oxygen as the lighter. This illustrates the law of .... It says ....

12. The equation in words for the preparation of hydrogen peroxide is ....
Gay Lussac's Law says: ....
....

TABLE V

RESULTS OF TEST - UNIT 3.

Max. Mark - 100	Class I.		Class II.		Class III
	92	56	84	43	90
	84	52	80	40	90
	83	50	74	38	84
	80	50	72	38	82
	78	48	70		82
	75	44	67		82
	74	40	66		80
	74	35	66		79
	74	32	66		78
	70		66		78
	70		66		76
	70		64		74
	70		64		70
	70		62		70
	70		62		70
	70		61		70
	69		59		70
	68		58		68
	66		58		68
	65		56		66
	64		56		64
	64		55		64
	64		52		64
	64		52		62
	62		52		62
	60		50		60
	60		50		60
	60		48		60
	56		56		58
	56		45		48
Totals	2489		1986		2129
N -	39		34		30
Median -	64		59		70
Average -	63.8		58.4		70.9

Comment. The medians and average marks correspond closely in the above results. Class III shows a marked superiority over the other two. The poor showing of Class II

may have been due to the lack of interest indicated by this class and referred to already in the discussion of results of units I and II. Class I still maintained their initial enthusiasm for the work book method and many wanted to go ahead at a faster rate than the limitations of the unit permitted.

CHAPTER V.

UNIT 4 - ATOMIC-MOLECULAR THEORY, CHEMICAL EQUATIONS AND CHEMICAL ARITHMETIC.

Procedure.

Class I. Lessons 6 and 7 of the work book were completed. This unit being general theory required no laboratory work. The students seemed to find considerable difficulty with this unit and required much help in the understanding of equations and problems.

Class II. Chapters VII, VIII and IX of Black and Connant's text were covered in a series of lessons by the teacher. Daily reviews and much practice in writing of equations and working of problems was given. The students made notes by summarizing selected sections from the text.

Class III. No pretest was held as this unit involved entirely new and difficult material.

Presentation. The essential adaptation in this unit appeared to be the use of symbols in equations and the understanding of the concept of valence, radicles and the principles underlying chemical nomenclature. Fully four repetitions were required before many in the class were able to attain the required 85% on the presentation test. Assimilative material involved Chapters VII, VIII and IX of Black and Connant's text.

The unit test (Page 28) was then administered to the three classes and Class III continued to work on the assimilative material until the whole class had mastered the unit.[1]

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[1] The equations and problems were different in the subsequent tests however.

A written report involving a summary of the principal sections of the text was then made. No oral reports were required.

Unit Test, Unit -4- Atomic Theory, Chemical Equations, and Chemical Arithmetic.

Fill in the blanks below:-

1. An hypothesis is a scientific .... A theory is an accepted .... A law is a .... based on ....

2. The fundamental laws of chemistry can be explained by Dalton's Atomic theory if we assume that all .... of a given .... are .... in size and weight but differ in these respects from other ....

3. An atom is ....
A molecule is ....

4. When a stream of hydrogen gas is blown over an electric arc, ... takes place. The .... hydrogen so formed combines at a short distance from the arc to form .... producing a temperature of around .... degrees centigrade.

5. The valence of oxygen is .... This means that one .... of .... can unite with .... atoms of .... The formula NH_3 tells us that nitrogen is .... valent.

6. Given the symbol for iron is Fe with a valence of 2 or 3, and of mercury is Hg, with a valence of I or 2, write the formulae as required below:

Ferric sulfide .... Mercurous oxide......
Ferrous nitrate .... Mercuric chloride .....
Ferric sulfate .... Mercurous carbonate .....

7. Write names for the following:

Unit Test, Unit 4, (continued)

7. (con't'd.)

$FeBr_3$ .... HgS..............

$Fe(ClO_3)_2$ .... $Hg\ (OH)_2$.........

$Fe_2(SO_3)_2$ .... $Hg\ ClO_2$ ....

8. Write balanced equations for the following reactions:

(a) The explosion of a mixture of hydrogen and oxygen.
(b) The burning of phosphorus in air.
(c) The decomposition of mercuric oxide by heat.
(d) The decomposition of potassium chlorate by heat.
(e) Magnesium dissolves in sulfuric acid.
(f) Sodium acts on water.

9. Fifty grams of copper oxide are reduced to metallic copper in a stream of dry hydrogen. Compute (a) the weight of hydrogen required, (b) the weight of copper formed, (c) the weight of water formed. (H-I, Cu - 64, O-16.)

TABLE VI

RESULTS OF TEXT UNIT 4.

Max. Mark - 100	Class I	Class II	Class III
	93	83	69
	80	78	63
	72	76	63
	69	73	61
	69	73	61
	67	72	60
	60	71	59
	58	71	57
	56	70	56
	55	69	56
	55	69	56
	53	68	56
	52	66	54
	52	65	52
	48	65	52
	47	65	51
	46	64	51
	46	62	50
	46	58	50
	46	57	50
	45	57	46
	42	56	41
	41	54	41
	41	51	37
	40	51	35
	40	50	32
	40	49	31
	40	48	18
	40	48	
	37	46	
	35	43	
	35	42	
	31	36	
	30		
	30		
	29		
	28		
	26		
Total	1820	2006	1434
N -	38	33	29
Median -	46	64	52
Average -	48.0	60.8	49.5

Comment. In this unit a marked superiority is observed in the case of class II. Previously this had been the weakest class but in this unit it surpasses Class III by twelve marks on median and average scores, and Class I by from 13 - 18 marks.
The weakness of Class II in units 1, 2 and 3 was attributed in part to an inferior attitude as far as attention and interest were concerned. Their success in this unit cannot, however, be attributed to a sudden stimulation of interest in the work. At least, there was no special evidence to this conclusion. The material involved in this unit, as has been pointed out, is highly theoretical. There was no laboratory work to engage their interest and any improvement in attention could only have been attributed to their having settled down and accustomed themselves to the teacher and the methods of instruction.

The explanation seems to lie rather in the fact that the other two classes fell far below their possible attainments in this unit. The reason for this is doubtless that the methods of instruction were not suitable to this particular unit.

In Class I the work book method, or at least these particular lessons in the work book, proved quite inadequate to teach the difficult theoretical work of this unit. Even with the help accorded by the teacher their results were very inferior.

In Class III the difficulty seemed to be to determine what "essential adaptation" was involved in the unit. The concept of the chemical equation and its use in chemical arithmetic, the fundamental rules of nomenclature and atomic-molecular theory proved difficult to reduce to any easily digested thirty-minute lesson. Even when they had passed the presentation test they were not equipped adequately to work independently on the assimilative material of the text. There is no doubt that for this unit, at least, Classes I and III should have had as careful teaching on the whole range of the topic as Class II had. These,of course, are the results of the first test on the unit. Further time was spent by all three classes on improving their rating.

CHAPTER VI.

UNIT 5 - SALT AND RELATED COMPOUNDS.

Procedure.

Class I. Lessons 8 and 9 of the work book were completed by the class. Experiments 15, 16, and 17 were demonstrated by the teacher. Experiment 17 was performed by the class individually working from mimeographed instructions.

Class II. The subject matter of Chapters X and XI, Black and Connant's text, were taught by means of lessons and reviews by teacher. The Class made notes from selected sections of the text. The same experimental work as for Class I was carried out, only with verbal amplification by the teacher.

Class III. A period was taken for a preliminary survey. This involved class discussion on salt and its uses, products and related compounds. In a half-hour presentation the essential facts concerning the chemistry of salt, chlorine, hydrogen chloride and sodium hydroxide were covered. This lesson required several repetitions (four for the majority of the class, five or six for some.) It eventually resolved itself into the memorization of ten essential equations and it was probably due to their lack of success with the last unit on equations that gave rise to the difficulties here. Assimilative material included Chapters X and XI of Black and Connant's text with

reference in Cornish's Chemistry and Bradbury's Elementary Chemistry. The same laboratory work as for the other classes with the demonstrated experiments performed by small groups instead of by the teacher completed the unit.

A written report followed the unit test and two periods were devoted to oral work.

Unit Test. Unit 5 - Salt and its Related Compounds.

1. Salt, when obtained from the ...., cakes in moist air because it contains .... This substance is .... i.e. it absorbs moisture.

2. In the electrolysis of brine the final products are .... and ....

3. The metal sodium is prepared from .... by the process of .... To preserve sodium it is kept under ....

4. Three important uses for sodium hydroxide are (I) .... (2) ....
(3) ....

5. Chlorine is prepared in the laboratory by the action of .... on .... The equation for the reaction is :........................
....

6. Three elements which unite readily with chlorine are .... and ....

7. Turpentine has the formula .... In the presence of chlorine the .... of the turpentine unites to form .... and is liberated.

8. Chlorine water bleaches because it changes into .... acid. This acid is unstable and gives off .... which then combines with the dye. The equation for this is:- ....
....

Unit Test, Unit 5 (con't'd.)

9. Complete :- $Cl_2 + 2\ NaOH$ --- + + .
The names of the salts so obtained are ....
& ....

10. Chloride of lime is made by the action of ....
.... on .... When sulfuric
acid acts on chloride of lime the reaction is :-
....

11. Hydrogen chloride is prepared by the action of
.... acid on .... An
equation for the reaction is :- ....
....

12. Hydrogen chloride dissolves in water forming
.... This solution will give a
white precipitate with ....
The action of this solution on magnesium is
represented by the equation :-..............
....

13. The white precipitate named in (12) is an indication of the presence of a ....
in the solution. This white precipitate is
insoluble in .... , but dissolves
readily in ....

14. Hydrogen and chlorine unite in the proportion
of .... by volume. Commercially this
symthesis is carried out in tubes made of ...
.... Water is then added forming
....

15. Dakin's solution contains .... It is
used for .... The solution must be
quite .... when prepared.

TABLE VII

RESULTS OF TEST - UNIT 5.

Max. Mark - 100	Class I.	Class II.	Class III
	84	83	83
	80	75	80
	71	74	74
	67	68	74
	66	66	72
	65	62	71
	59	62	68
	57	62	68
	57	59	68
	54	58	68
	51	56	66
	50	56	65
	48	53	64
	48	52	64
	48	50	60
	43	49	60
	41	48	58
	40	44	56
	39	42	54
	38	40	51
	38	40	50
	38	38	49
	36	33	48
	35	33	48
	34	32	44
	32	30	42
	30	26	42
	30	25	38
	29	22	26
	28	16	
	28	13	
	28		
	26		
	23		
	23		
	22		
	22		
	21		
	19		
	12		
Total -	1660	1467	1711
N -	40	31	29
Median	38	49	60
Average -	41.5	47.3	59.0

Comment. On the median score Class II is seen to be 11% above Class I, and Class III, 11% above Class II. The averages show similar differences. With the introduction of equations the Morrison technique, with its more intensive teaching of essentials, shows to advantage. The marks are low for Classes I and II. Apparently they were not properly prepared for the test and more time was spent on this unit in all three classes.

CHAPTER VII.

UNIT 6 - IONIZATION AND NEUTRALIZATION.

Procedure.

Class I. Lessons 10 and 11 of the work book were completed. Laboratory experiment 20 was performed by the class individually from black board instructions. Experiment 21 was demonstrated by a group of four students.

Class II. Chapters XII and XIII of Black and Connant's text were taught in a series of reviews and recitation periods. Brief notes on selected sections were written. The laboratory work was the same as for Class I.

Class III. No pretest was held since this unit involved difficult theory of which the class was not likely to have had any previous experience. In the presentation lesson, the bare essentials of the ionization theory and of neutralization of acids and bases was taught. This was repeated until all had made the necessary adaptation.

Assimilative material included Chapters XII and XIII of Black and Connant's text with laboratory work as in Class I. The unit test (p. 39) was then administered to all three classes. A report of the unit was then written by this class but no oral work was assigned.

Unit Test. Unit 6 - Ionization and Neutralization.

Complete the following:-

1. To produce sodium chloride it is necessary to neutralize .... with ....

2. The essential change involved in neutralization is the union of .... and .... to form ....

3. An acid found in fruits is .... The base formed when ammonia dissolves in water is called ....

4. A substance which will not carry a current of electricity when dissolved in water is called a .... An example of this is ....

5. According to the ionization theory when salt is dissolved in water its molecules at once .... into .... charged particles called .... and charged particles called ....

6. Complete with ionic equations:-
    (a) $CaCl_2$ ....
    (b) H_3PO_4 ....

7. In an experiment to determine the strength of an unknown solution of an acid four essential requirements are :-
    (i) .... (ii).............
    (iii).................. (iv).............

8. To exactly neutralize 8 cc. of 0.5 N sodium hydroxide solution .... cc. of 0.I N sulfuric acid would be required.

9. In the electrolysis of brine ...... ions collect at the anode; each ion then .... one electron and becomes an atom of .... the final product at the anode is .... At the cathode .... ions collect; each of these ions .... one electron becoming an atom of .... The final cathode products are .... and ....

10. .... grams of sodium chloride in .... grams of water depresses the freezing point of water 3.72 C. This is

Unit Test, Unit -6- (con't'd.)

(10. con't'd.)
an .... depression caused by
the .... of sodium chloride
.... into ....ions.

11. Complete with ionic equations:-

(i) $Zn + 2H^+ + SO_4^=$ ....
(ii) $Ag^+ - NO_3^- + Na^+ + Cl^-$ ....

12. Equation (i) above goes to completion because ....
....
Equation (ii) above goes to completion because ....
....

TABLE VIII.

RESULTS OF TEST - UNIT 6.

Max. Mark - 100	Class I.	Class II.	Class III.
	76	88	78
	76	84	76
	74	84	76
	74	80	74
	70	74	74
	70	68	72
	70	68	70
	68	66	70
	68	65	68
	68	64	68
	68	64	64
	66	64	62
	66	62	60
	64	58	58
	60	58	58
	60	56	56
	58	54	56
	56	54	54
	54	52	54
	54	52	52
	54	52	52
	54	50	50
	52	50	50
	52	42	48
	50	40	48
	50	38	46
	48	35	44
	48	34	34
	48	25	
	46	24	
	46	24	
	46		
	46		
	46		
	42		
	42		
	40		
	46		
Total =	2156	1729	1672
N =	38	31	28
Median =	55	56	58
Average =	56.7	55.8	59.7

Comment. On the basis of the medians and averages considered together Class I and Class II are about equal.Class III is approximately 4 points superior to these others. The work book required considerable amplification in this unit. Hence, perhaps, the equality of Classes I and II. The slight superiority in the case of class III is again doubtless due to the extra teaching of the essentials. Generally speaking this unit does not offer reliable information in this comparison of techniques. It was used, for one thing, as a means of equalizing the three classes in the matter of progress in covering the course. There was a tendency for Class III to get behind the other classes and since it was necessary to administer the same test on the same day to the three classes it was thought advisable to bring this class up to the level of the other two on this unit. This unit was selected because it is theoretical chemistry of a type not strictly essential for a beginner, and an inadequate treatment would not raise any serious difficulties for subsequent units of the course. For this reason Class III covered the unit very rapidly but despite this they showed to better advantage in the unit test.

CHAPTER VIII.

UNIT 7 - SULFUR AND ITS COMPOUNDS.

Procedure.

Class I. Lessons 12 and 13 of the work book were filled out and the examination questions were answered with class discussion. Laboratory experiments included #24 and #27, Black's Laboratory Manual, performed by students from instructions written on the blackboard, #25 and #26 performed by the teacher.

Class II. Chapters XV and XVI, Black and Connant's text were covered by the teacher in a series of lessons with daily reviews. The same laboratory work as for Class I was conducted only with verbal amplification in the case of individual work. Notes were written by summarizing selected sections and writing reports of laboratory work.

Class III. A pretest was conducted to ascertain the present knowledge of the class on the subject. This consisted of class discussion on sulfur, its uses and compounds.

In a thirty-minute presentation the essential facts concerning the chemistry of sulfur, hydrogen sulfide, sulfur dioxide, sulfur trioxide and sulfuric acid, with the principal equations were set forth. This was tested and retaught until most of the class had attained 85% on a test.

The assimilative material included Chapters XV and XVI of Black and Connant's text with laboratory work as in Class I, only working from laboratory manuals.

The unit test, page 44, was then administered to the three classes with Class III restudying the assimilative material until all the class had mastered the unit.

A report of the unit was written and a period of oral work completed the unit.

Unit Test, Unit 7 - Sulfur and its Compounds.

Fill in the blanks below:-

1. The purest natural sulfur is found in .... The sulfur obtained from Sicily is of .... origin. The Frasch method of mining sulfur uses .... to .... the sulfur, after which it is brought to the surface by means of ....

2. If powdered sulfur is dissolved in .... crystals of .... sulfur are obtained. By gently heating sulfur until it melts, ... is obtained. Sulfur boils at .... C. If this boiling sulfur is then poured into cold water we get .... sulfur.

3. A hot copper wire held in the fumes of boiling sulfur becomes coated with .... The equation is : .... The tarnish on silver is ...., formula ....

4. The juice of the rubber tree is called ...... When acetic acid is added we get .... To make automobile tires, ... and .... are then added and heated. This process is called ....

Unit Test, Unit 7 (con't'd.)

5. Hydrogen sulfide is best prepared by the action of .... on .... The equation is .... This gas is identified by its action on .... paper which it turns ....

6. Hydrogen sulfide burns with a .... flame. The equation for this combustion is .... When a cold dish is held in this flame a deposit of .... is formed. The equation in this case is ....

7. A water solution of H_2S is called .... It is a.................. acid and its salts are called .... It ionizes thus:- ....

8. Complete and balance indicating the colors of any precipitates:-
   (a) $H_2S + CuSO4$ ....
   (b) $H_2S + SbCl_3$ ....
   These equations illustrate the importance of H_2S in ....

9. When carbon and sulfur are heated together we get .... This process requires a .... temperature because the product is an .... compound. It is used for .... and for ....

10. Commercially, sulfur dioxide is obtained by .... In the laboratory we treat .... with .... The equation is ....

11. The water solution of sulfur dioxide is called .... This compound is very .... Its salts are called .... If the solution is neutralized with sodium hydroxide we get ...., the formula being ....

12. Sulfurous acid will decolorize a purple solution of .... This illustrates the .... action of sulfurous acid. In this reaction the sulfurous acid is itself .... to ....

13. The molecule of a dibasic acid contains ...... atoms of .... Phosphoric acid is a .... basic acid. P2O5 is the .... of phosphoric acid.

Unit Test. Unit 7 (con't'd.)

14. When slaked lime is treated with an excess of sulfur dioxide ....is formed. Its formula is .... and it is used in the .... industry for removing .... from ....

15. Sulfur trioxide is made by heating .... and .... in the presence of .... as a catalyst. The equation is :- ....

16. In the Contact process for making sulfuric acid the catalyst is .... in this process the gases must be .... or else the catalyst does not function properly. The product from the Contact tower is .... This is dissolved in .... and forms ....

17. In the Lead Chamber process the catalyst is .... The purpose of the Gay Lussac Tower is to .... This is done by means of .... The Glover tower is designed to .... If pure 100% sulfuric acid is required the .... process is best.

18. We test for a sulfate with a solution of .... This gives a .... precipitate, insoluble in .... The equation, using sodium sulfate, is :; Na_2SO_4 + ...

TABLE IX.

RESULTS OF TEST - UNIT 7.

Max. Mark - 90	Class I.	Class II.	Class III.
	80	70	67
	68	67	62
	68	61	59
	63	61	58
	56	59	58
	56	56	57
	54	56	54
	53	52	54
	53	50	53
	53	50	49
	52	50	47
	52	49	46
	50	48	46
	50	47	45
	48	46	44
	48	46	44
	47	46	43
	46	44	40
	46	43	40
	45	43	39
	42	41	38
	41	40	38
	41	40	37
	40	39	36
	40	37	33
	37	33	32
	34	31	30
	33	31	30
	32	26	26
	30	25	23
	29	21	
	27	16	
	25	13	
	25		
	25		
	25		
	22		
	21		
	15		
	15		
Total -	1688	1437	1328
N -	40	33	30
Median -	43.5	46	44
Average	46.9%	48.5%	49.2%

Comment. On the basis of the median mark Class II shows a slight superiority; on the basis of the average Class III has a slight advantage. There is no conclusive difference in this unit except that Class I scores the lowest. It is to be noted that the material of this unit differs from that of the preceding two units in that it is mainly factual and free from any difficult theory that requires careful explanation. The result is that Class I managed very well with their work books. The slight inferiority of the results in this class might very well be attributed to their failure to handle equations successfully. This class seemed handicapped in this regard for most of the remaining part of the course.

With the careful study of essentials made by Class III, this group might have been expected to make a much better showing. That they failed to do this may possibly be due to the fact that the test demanded a knowledge of much detail. This should have been acquired in the study of assimilative material but evidently the class failed to profit by their individual study, at least up to the time of the first testing on the unit as a whole.

Class II probably benefited by the daily practice in writing equations which constituted a part of the short review before proceeding with the daily present-

ation of new material.

This unit was considered a good unit for a comparison of the three techniques and the uniformity in the results has significance and will be further discussed in the general conclusions.

CHAPTER IX.

UNIT - 8 - CARBON AND ITS COMPOUNDS.

Procedure.

Class I. Lesson 14 of the work book was completed together with the questions. Laboratory work included Experiments 30 and 31 of Black's New Practical Experiments performed by the students individually from instructions written on the board and experiment 32 performed by the teacher.

Class II. Chapter XVII of Black and Connant's New Practical Chemistry was taught in a series of lessons with brief daily reviews. The laboratory work was the same as for Class I. The Class wrote notes on selected sections of the text and complete reports of all laboratory work.

Class III. A pretest consisting of general class discussion on coal, charcoal, coke and other forms of carbon and the oxides of carbon. This pretest revealed a good general knowledge of the subject and served as a guide in the presentation of the new material. The essential adaptation in this unit was deemed to be the relation of carbon, carbon dioxide, carbonic acid and the carbonates. This was taught with reference to the main equations involved and required not more than two teachings for the greater number of the class. Assimilative material involved all the practical and commercial applications of these related forms and compounds of carbon as set forth in Chapter XVII of Black and Connant's text together with

the laboratory experiments as listed for Class II, only with the demonstrated experiment (#32) performed by members of the class.

The unit test in this case was not a prepared mimeographed test but a short-answer test from questions dictated by the teacher. These questions are given below. The unit was completed in the case of this class with a written report and a period of oral talks by members of the class on selected topics of the unit.

Unit Test Unit -8- Carbon and its Compounds.

1. Name two properties and two associated uses for diamond.

2. Name two properties and two associated uses for graphite.

3. Explain briefly how the following are prepared artificially:
   (a) graphite, (b) charcoal, (c) coke.

4. (a) Name two by-products obtained in the manufacture of charcoal.
   (b) Name three by-products obtained in the manufacture of coke.

5. How is lampblack made? Name two of its uses.

6. Name two uses for animal charcoal which make use of its porous characteristic.

7. Write equations for:- (a) The burning of carbon, (b) The effect of adding water to the product form. (c) Name the products.

8. Write the equation for the laboratory preparation of carbon dioxide.

9. Describe the test for carbon dioxide.

10. Write the equation for the above and indicate any precipitate and its color.

Unit Test, Unit -8- (con't'd.)

11. Describe a commercial use for carbon monoxide. Explain how the inhaling of carbon monoxide causes death.

12. Describe the use and operation of a fire-extinguisher containing bicarbonate of soda.

13. Write the equation involved in this fire-extinguisher.

14. Name two other uses for carbon dioxide.

15. Write equations to represent what happens in the three main regions of a brightly burning coal fire.

TABLE X.

RESULTS OF TEST - UNIT 8.

Max. Mark - 60	Class I.	Class II.	Class III.
	54	53	53
	52	49	52
	51	46	51
	51	45	46
	48	43	45
	48	43	45
	47	43	43
	46	43	43
	44	40	39
	43	40	39
	43	39	39
	43	38	39
	42	37	38
	41	35	38
	41	35	38
	40	35	38
	40	35	34
	37	35	33
	35	34	33
	34	30	33
	32	28	32
	32	27	29
	30	26	22
	30	25	22
	30	24	21
	30	23	20
	28	17	19
	25	14	
	25	13	
	24	13	
	22		
	21		
	19		
	15		
Total -	1243	1008	984
N -	34	30	27
Median -	38.5	35	38
Average -	36.6	33.6	36.5
Average % -	61.0	56.0	60.8

Comment. In this unit we find Class I slightly superior to the other classes. This was the only unit in which this class surpassed the others. It will be noted that the number of students is less in this unit for each class but particularly so for Class I, which normally numbered 40. As far as Class I was concerned, of the six unrecorded students one had left school and the remaining five were absent most of the time this unit was studied . Three of these failed on the year's work, but at least one of the other two was a superior student so that it could hardly be said that the absence of these five students accounted for the better showing of this class. The more probable reason was that this unit was highly objective as to subject matter and lent itself particularly well to study by the work book method.

There would seem little reason however, why the other classes could not benefit equally from this objectivity of subject matter and still show further benefit resulting from the teacher's emphasis on the more difficult phases of the work.

The only possible explanation, aside from the improbable one that the teacher's efforts merely result in a negative effect, is that dependence on the teacher's explanations renders the students unfit or unwilling to study privately from the text.

A further discussion of this point appears in the general summary.

CHAPTER X.

UNIT 9 - NITROGEN AND ITS COMPOUNDS.

Procedure.

Class I. Lessons 16, 17 and 18 of the work book, together with selected questions from the text were completed. The following experiments from Black's "New Laboratory Experiments" were demonstrated by the teacher:- Nos. 37, 39, 41, 42, and 43. None of the experiments on this section were suitable for individual work by the students.

Class II. The material of Chapters XIX, XX and XXI of Black and Connant's "New Practical Chemistry" were taken up by the teacher in a series of review and recitation periods covering about three weeks. The laboratory experiments as listed above for Class I were demonstrated. Questions from the text at the end of each chapter were prepared by the Class and were taken up in class. Reports of all laboratory work and notes on selected sections of the text were written by the students.

Class III. A preliminary discussion on the atmosphere, certain compounds of nitrogen, plant nutrition in relation to nitrogen, explosives and fertilizers was used to introduce the topic. The essential adaptation in this unit was deemed to be the fact of the instability of nitrogen compounds as exemplified in the saltpetres, nitric acid, ammonia, oxides of nitrogen, fertilizers and explosives. This was taught together with the

principal equations involved in a thirty-minute period and repeated until the great majority had made the adaptation. Assimilative material involved Chapters XIX, XX, and XXI of the text together with the laboratory experiments some of which were demonstrated by groups of students. Reports of the unit were written up but no oral work was carried out on account of the shortness of time.

The unit test which preceded the written reports was the same for the three classes and is reproduced below. Class III repeated the test until all had mastered the unit.

Unit Test. Unit -9- Nitrogen and its Compounds.

1. Pure nitrogen may be prepared by heating .... The equation is : The chief commercial source of nitrogen is ....

2. Nitrogen is chemically .... Three elements it will combine with are ...., and ...., ...

3. In the manufacture of liquid air, air is first .... It is then ...., and finally allowed to .... By this means a temperature of .... is attained.

4. Gas-filled electric lamps may contain .... or .... They prevent .... Helium is used for ....

5. The best laboratory method of preparing ammonia is by heating a mixture of .... and .... The equation is .... The gas is collected by ....

Unit Test, Unit 9 (con't'd.)

6. A solution of ammonia is called .... It is .... to litmus and is used in the household because it .... It ionizes thus:- ....

7. In theHaber process for the synthetic production of ammonia the necessary conditions are (I) a .... pressure. (2) a .... temperature and (3) a .... The equation is : ....

8. Ordinary saltpeter is .... It is used especially for .... and .... Chile saltpeter is .. .. It is used in the manufacture of ....

9. The equation for the laboratory preparation of nitric acid is: .... The yellow color of concentrated nitric acid is caused by .... The equation for the decomposition of nitric is: ....

10. When dilute nitric acid acts on copper the products are ...., ... and .... The equation is:- ....

11. Aqua regia is a mixture of nitric acid and .... and is used to dissolve ... . To test for a nitrate we use .... and .... The result is ....

12. Of the three oxides of nitrogen, ... will relight a glowing splint, ... combines with oxygen and the last, namely ...., dissolves in water forming nitric acid. The equation for the last is:- ....

13. Smokeless gunpowder is made by the action of .... on .... Dynamite contains .... soaked in ....

Unit Test, Unit -9- (con't'd.)

14. In the cyanamide process for the fixation of nitrogen, ... gas is passed over .... producing .... This solution treated with steam produces ammonia according to the following equation:-............ ....

15. In nature, free nitrogen is converted into compounds by the action of .... It is absorbed by plants and animals helping to build up .... which as waste products are broken down by the action of .... into .... Certain plants called .... contain bacteria in their roots.

TABLE XI.

RESULTS OF TEST - UNIT 9

Max. Mark - 70	Class I.	Class II.	Class III
	65	51	62
	55	50	57
	51	49	56
	49	46	50
	45	43	50
	44	42	50
	43	41	49
	43	41	47
	41	39	46
	40	39	42
	39	39	41
	36	39	41
	35	39	39
	35	38	39
	33	38	38
	32	38	38
	31	36	37
	30	35	36
	30	33	35
	30	33	34
	29	33	34
	28	32	33
	28	30	32
	26	30	32
	25	28	31
	23	25	31
	23	23	31
	23	22	26
	23	21	23
	22	20	
	22	16	
	17	7	
	16		
	14		
	14		
	12		
	11		
	11		
Total -	1174	1096	1160
N -	38	32	29
Median -	30	37	39
Average %	44.1	49.0	57.1

Comment. On the basis of the median mark Class II and Class III are about equal. The average expressed as a percentage shows Class III to be decidedly superior to both the others. This unit forms a good basis of comparison for the three classes. The work is fairly difficult and the classes should have been working at their best level in view of the fact that this was the last unit of the course and they had been urged to try to improve their individual standings with a view to raising their yearly average. If in view of this the marks seem rather low it might be well to point out that the test was fairly difficult and that the time available to the three classes for a study of this unit was reduced by a week or more owing to an earlier date being set for the yearly returns than had been expected.

Class I. shows up rather badly in this unit with an average of 44.1 per cent and a median mark of about the same (44.3%). The class needed much urging to keep their work books up to date and, despite the fact that most of them needed a good mark in this unit in order to improve their yearly average, many failed to make the necessary effort to prepare for the test.

CHAPTER XI.

ADDITIONAL TESTS.

In addition to the unit tests two other tests were administered during the course of the year. Both these were given to the students without warning and no special preparation was made by them.

The first of these was the Post-Christmas test and was administered early in January. It covered the work of the Fall term and was given with a view to see how much of the work had been retained over the holidays and, in fact, since the first of the school year. It is reproduced on page 62, and the results, with a discussion of their significance appear on page 63.

The second test was administered in June at the conclusion of the year's work. It consisted of selected questions from the 1937 Departmental Examination in Chemistry I. The students made no special preparation for this but were tested on three consecutive days with selected questions totalling 80 marks. The results and discussion appear on page 65. (See also Appendix I.)

In September, 1939, after the lapse of the summer holidays a test was administered to all those students who registered for the Chemistry II course. This consisted of a review test covering the work of Chemistry I. From the results of this test the marks of those students who constituted the three classes of this investigation were selected and a tabulation made. Results were obtained from 47 of the 98 who completed the course last year. The test together with the results appear on page 68.

Fall Review Test. (Administered January 5, 1939.)

1.. In the following, place the number of the substance in the bracket to which it best corresponds:-

(1) Mercury
(2) Sulfur
(3) Air
(4) Brass
(5) Granite
(6) Ozone
(7) Zinc Sulfate
(8) Hydrogen
(9) Carbon disulfide
(10) Brine

A Mixture ( )
An allotrope ( )
An Alloy ( )
A Metallic Element ( )
A Non-metallic Element ( )
A Reducing Agent ( )
A Salt ( )
A Solution ( )
A Solvent ( )
A Material ( )

2. Write equations for:-
(a) The preparation of oxygen from potassium chlorate.
(b) The preparation of hydrogen from sulfuric acid.
(c) The action of sodium on water.
(d) The burning of sulfur in oxygen.
(e) Steam is passed over red hot iron
(f) Solutions of silver nitrate and sodium chloride are mixed.
(g) The decomposition of hydrogen peroxide.
(h) Magnesium reacts with hydrochloric acid.

3. Write formulas for:-
Mercurous chloride .... Ferrous sulfide.......
Aluminum oxide .... Ferric hydroxide......
Sodium chlorate .... Ammonium nitrate......

4. Name the following:-
Hg_2SO_4 .... $Ca_3(PO4)_2$...............

$Zn(NO_3)_2$............... $HgSO_3$ ....

$CaCO_3$.................. AgCl ....

5. Name and state the laws illustrated in the following:-
(a) Hydrogen and oxygen unite in the ratio of 2:I by volume.
(b) Copper sulfide always consists of 66.7% copper and 33.3% sulfur.
(c) If 56 gm. if iron combine with 16 gm. of oxygen the iron oxide produced will weigh 72 gm.
(e) There is twice as much oxygen in carbon dioxide, for a given weight of carbon as there is in carbon monoxide, for the same weight of carbon.

TABLE XII

RESULTS OF POST-CHRISTMAS TEST.

Max. Mark - 100	Class I.	Class II.	Class III.
	91	91	93
	86	88	91
	83	87	84
	81	86	84
	80	83	80
	77	78	80
	75	77	80
	74	70	73
	65	68	73
	63	68	68
	61	67	66
	60	67	66
	59	66	64
	58	66	63
	55	66	62
	53	63	61
	50	60	60
	50	60	59
	48	58	59
	47	56	58
	45	56	57
	43	55	56
	39	54	48
	39	52	46
	37	51	40
	36	50	33
	36	50	32
	34	49	24
	33	47	21
	33	43	18
	32	42	
	29	40	
	28	38	
	27	30	
	27		
	24		
	22		
	16		
	14		
Total -	1910	2082	1799
N -	39	34	30
Median -	47	60	61.5
Average -	49.0	61.2	60.0

Comment. Classes II and III are seen to have about the same scores, the slight superiority of the one on the median mark being balanced by the slightly higher average of the other. The most significant fact is the low showing of Class I, especially in view of the fact that this class had compared favorably with the other classes particularly Class II on the unit tests administered at the time the units were individually completed. On the first four tests, that is, those on the units covered before Christmas, Class I had an average of 62.7%, Class II an average of 64.0% and Class III an average of 67.0%. These figures reveal a weakness in the case of Class I but not the difference which appears on the review test under discussion.

Classes II and III have an average superiority of 12 marks over Class I reckoned on either the median or average marks and this on the basis of 48% as the class average for Class I means a gradient of 25% superiority of these two classes over Class I.

Apparently there is conclusive evidence here of the fact that a stereotyped method of instruction of the work book type without considerable amplification by the teacher and careful review results in a weakness which, in its cumulative effects, is considerable.

TABLE XIII

RESULT OF JUNE TEST.

Max. Mark - 80	Class I.	Class II.	Class III.
	71	59	71
	55	59	70
	50	57	62
	50	56	61
	50	50	60
	50	50	58
	50	48	58
	46	48	57
	44	47	56
	43	45	54
	42	45	53
	41	43	52
	41	42	52
	38	41	51
	37	41	51
	36	40	50
	35	36	50
	35	36	50
	34	35	50
	33	33	46
	30	31	44
	28	31	41
	26	30	40
	25	30	33
	25	28	30
	25	27	30
	24	26	25
	24	25	24
	24	21	20
	22	20	
	20		
	20		
	19		
	18		
	17		
	17		
	17		
	12		
Total -	1308	1180	1399
N -	39	30	29
Median -	34	41	51
Average -	42.0%	49.1%	60.5%

Comment. The class average for Class III is 60.5 percent. This is quite a high average for a class to make on a departmental examination especially in view of the fact that no special preparation had been made; in fact, as far as the teacher was concerned, there had been no general review since the beginning of the year. The average for Class I, 42 percent, on the other hand, is low, whilst Class II strikes an approximate average between the two.

Expressed as a percentage increment, Class III exceeds Class I on the average mark by 43%, and Class II by 22%. Class II exceeds Class I by 16.7%.

However they are viewed these are significant differences. The class which had had the benefit of the Morrison technique surpassed the other two classes by a wide margin, its marks being nearly half as high again in the one case, and nearly one-quarter as high in the other.

As a general observation it might be stated that the students were not particularly enthusiastic about this test. They knew that the year's work had already been completed and that the final marks had all been compiled. The test was regarded therefore by the majority as a device to keep them occupied during the last few days of the year. The general application was therefore of a rather low level.

Those who were best prepared for the test however, became interested and did the best work. This might account in some measure for the marked superiority of Class III over Class I. This merely means, of course, that the results emphasize a disparity between the classes that was already there in fact.

Results of Review Test in Chemistry I.

The following are the results of a test administered to all those students who registered for Chemistry II after the summer holidays that is, subsequent to the year of the experiment. They are tabulated on Page 68 according to the class to which they belonged during the previous school year. The maximum value of the test was 150.

The I.Q's are listed with the marks for a reason which will become apparent during the discussion.

TABLE XIV.

RESULTS OF FALL REVIEW TEST.

Max. Mark = 150	Class I.		Class II.		Class III	
	Mark	I.Q.	Mark	I.Q.	Mark	I.Q.
	38	*	60	101	40	108
	42	100	59	101	32	109
	18	116	12	85	15	97
	24	109	91	128	46	102
	17	95	50	96	18	113
	68	134	55	106	50	100
	76	*	75	105	80	*
	38	*	36	122	23	99
	62	120	110	125	71	109
	70	128	85	120	62	90
	69	111	76	109	40	112
	59	122	72	98	110	104
	35	90	70	103	70	117
	63	121	39	100	60	112
					71	109
					96	100
					62	100
					85	113
					51	101
Totals -	679	1246	890	1499	1082	1895
N -	14	11	14	14	19	18
Average-	48.5	114	63.5	107	57.0	105
Median -	50	116	60	104	60	106

* I.Q's not available.

Comment. Only 47 of the original 100 students were covered by this test and the distribution of these students according to the three classes were in a different ratio to the original ratio. While it might be supposed that only the more successful students from the Chemistry I classes would register for Chemistry II, this is not necessarily the case and

we find, in fact, that a number of the students listed above barely obtained a pass on their Chemistry I course. Since this is a newly selected group it was deemed advisable to list their I.Q's along with their marks on this test, such I.Q's having some significance in a consideration of the results.

On the basis of the average marks Class II is seen to be noticeably superior to the other two, although Class III stands 9.5 points above Class I. The median marks rate Class II and Class III as equal at 60 with Class I at 50.

In considering the average I.Q.'s we find that Class I ranges itself around 115, whilst the other two classes range around 105 - 106. One or two conclusions may be arrived at from these figures. In the first place, despite their higher average I.Q. Class I rates low on this test, as in the June test. Their retention of Chemistry I over a space of two months rates only 33.3% on this test which was designed to cover only essentials.

In comparison with Class III, Class II has done much better in this test than in the June final test when it rated about 10 marks lower. (See Page 66) Apparently the retention of Chemistry I exhibited by Class II students is as good or slightly better than that exhibited by Class III students.

As to whether there is any significance in these results in terms of the relative techniques will be discussed in the general conclusions (page 91)

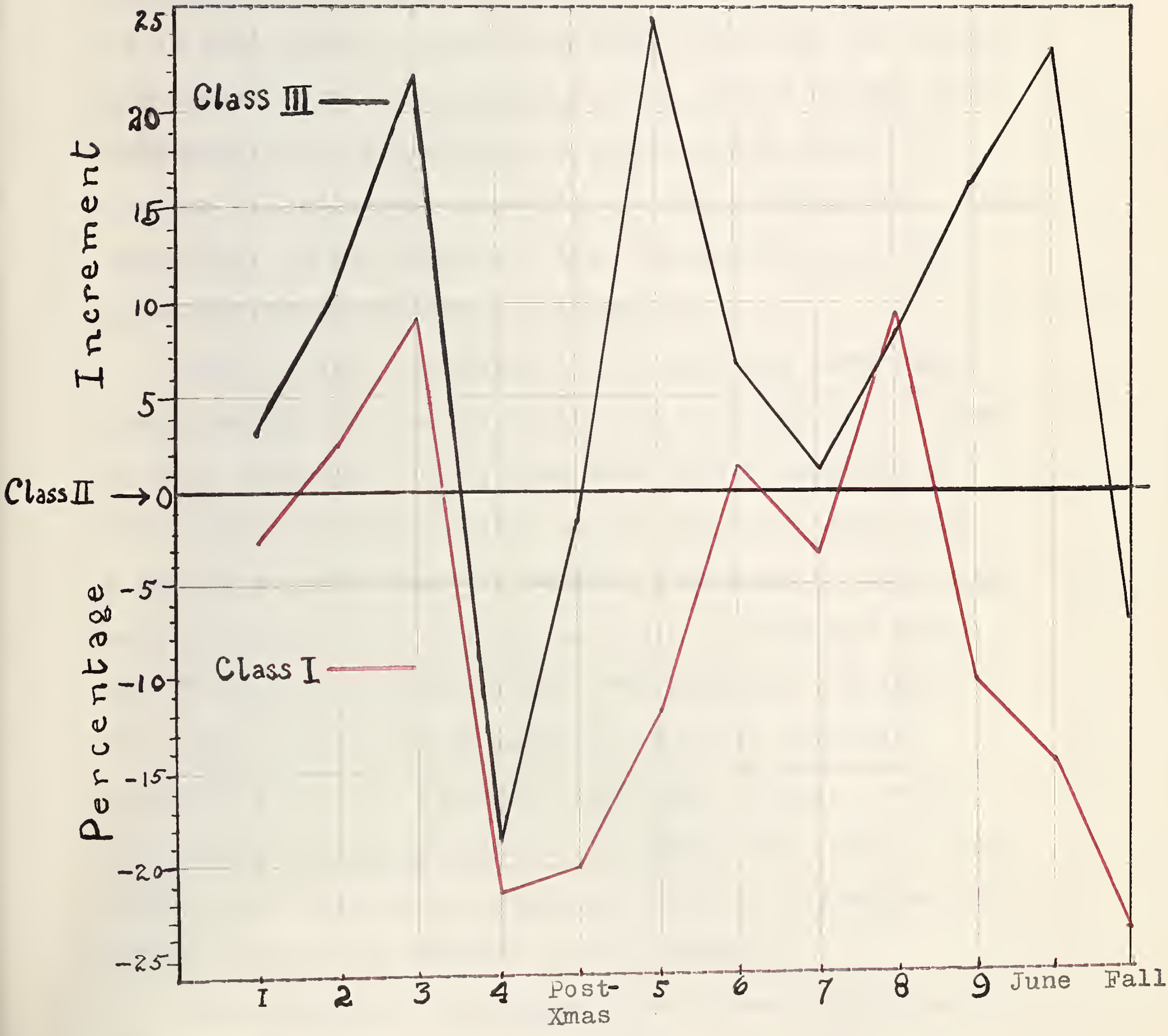
The second conclusion which might be made is that only those students of high I.Q. in the case of Class I registered for Chemistry II as compared with other classes. In view of the limited number of cases studied this may be only a coincidence but the figures lend themselves to the interpretation that the students of Class I who had been subjected to the work book method had failed to have their appetite for the subject sufficiently stimulated to make them feel like coming back for more. It is to be expected that only the brighter students would be able to benefit adequately from a method of study which was essentially a matter of self-education.

TABLE XV

A summary of the results of all tests, showing average and median marks for each of the three classes, together with the percentage increment of the Class I and Class III averages over Class II averages, the latter being taken as a standard of comparison.

	Class I			Class II		Class III		
Test - Number and description.	Av.	Med.	%Inc.	Av.	Med.	Av.	Med.	%Inc.
1. Chemical Change	70.0	73.3	-2.8	72.0	73.3	74.2	73.3	3.1
2. Combustion	68.5	70.0	2.6	66.8	68.0	73.4	72.0	10.5
3. Hydrogen	63.8	64.0	9.3	58.4	59.0	70.9	70.0	21.4
4. Chemical Arith.	48.0	46.0	-21.5	60.8	64.0	49.5	52.0	-18.6
5. Salt & Its Comp.	41.5	38.0	-12.3	47.3	49.0	59.0	60.0	24.7
6. Ionization	56.7	55.0	1.6	55.8	56.0	59.7	58.0	7.0
7. Sulfur & Comp'ds.	46.9	48.3	- 3.3	48.5	51.1	49.2	49.0	1.5
8. Carbon & Comp'ds	61.0	64.0	9.1	56.0	58.3	60.8	61.0	8.6
9. Nitrogen	44.1	42.8	-10.0	49.0	52.9	57.1	55.7	16.5
10. Xmas Review	49.0	47.0	-20.0	61.2	60.0	60.0	61.5	-2.0
11. June Final	42.0	42.5	-14.4	49.1	51.3	60.5	63.8	23.2
12. Fall ('39) Rev.	32.3	33.3	-23.5	42.2	40.0	38.0	40.0	-7.6

GRAPH SHOWING PERCENTAGE INCREMENT OF CLASS I AND CLASS III AVERAGE MARKS OVER CLASS II'S .



Unit Test (number or description).

CHAPTER XII.

DISCUSSION OF RESULTS.

The comparison of different class room techniques cannot be based entirely on examination results, important as these are in their ultimate appraisal. It is well known to educationalists that when the student and teacher are to be judged on the results of one final examination it is possible to achieve high marks by a process of judicious selection and elimination which, while succeeding in its immediate aim, defeats the real purpose and end of education ultimately.

Even in this investigation where there were twelve tests spread over twelve months and designed not to pass or fail students, but to determine their knowledge of the subject of instruction, it was realized there were a number of other factors besides the marks to take into consideration, such factors as could be observed from day to day in the class room. For example, a technique which achieved high marks but aroused antipathy on the part of the student towards the subject, could not be regarded as educationally sound, nor could a technique which shifted all responsibility in the matter of education from the student to the teacher.

In attempting to appraise these three techniques it would be well to consider each in the light of these satisfactions or dissatifactions first before venturing to

judge them in terms of quantitative results.

The Work Book Method.

Although many educationalists are not prepared to consider such a mechanical stereotype as the Work book or Outline Course as a bona fide class room technique, there are many who regard its use as justifiable on the grounds that it constitutes a solution to the problem of increased teacher loads. When the teacher is confronted with classes of from forty to sixty or more in number, the prepared work book can be of great assistance in releasing him from the necessity of "teaching" every single item on the course and leaves him free to give individual assistance to the slower members of the class.

It also removes one of the students' most frequent grievances; namely, the necessity of writing pages of notes. The work book is their note book, and while the answering of the study questions ultimately amounts to the same thing as writing notes, there is the ever-present stimulus of the question which makes the work that much less mechanical.

As far as the students' reaction to the work book was concerned, there was little sign of active antipathy to it as such. On the contrary, as stated in Units I and II there was evidence of an initial enthusiasm for the new method which launched many of the

students into the course with a momentum which overcame the inertia frequently encountered in the Fall term. Their energies showed signs of lagging after a few months however, and many needed much urging to keep their work books up to date as the year went on.

The great value of the work book seems to lie in its objectivity. There need be no class periods which "miss fire" because the teacher has not prepared a good lesson or for some other reason. The work is there, set forth in due order, and all the student has to do is to "fill in the blanks". As will be pointed out later there is a great danger in this very objectivity, but the point to note at the present is that students generally react well to a situation which is definite, concrete, and uniform from day to day. It also affords a relief from the too constant demand made by successive teachers throughout the day for students to "pay attention", or, to put it another way, it is so much easier for the student to concentrate the attention on a task when it calls for individual effort with pen and paper.

It is, of course, in the correspondence course that the work book has the greatest application. This is a field of education which has extended enormously in recent years and has assumed a position of very great importance particularly in relation to technical subjects, trades and skills.

So extensive is the correspondence course in the field of adult education that it is a matter of some importance to determine the relative value of such instruction as compared with ordinary class-room instruction, for it seems generally agreed by Universities and Departments of Education that credits obtained in this way are of equal value to those obtained intramurally.

As far as this investigation was concerned, the original intention was to try to parallel in Class I the conditions affecting the average correspondence student in relation to the subject. However, instead of each lesson being corrected by the teacher with written comments, in this case the examination questions were made the subject of class discussion and corrected verbally.

For the first half of the course very little class instruction was given by the teacher. The students were simply put to work on the work book, and such work was only interrupted for experimental work or the correction of exercises.

Later in the year, however, it was found necessary to give careful instruction in some of the more difficult chapters in order not to sacrifice the interests of the students of this class in the course of the investigation.

A further advantage that this class enjoyed over the average correspondence student was in the laboratory work which, particularly in a science subject, must greatly enhance the value of a course.

Now as to the results obtained in Class I, it is to be noted that at first they are not greatly inferior to those obtained in Class II or Class III. Up to Christmas Class I had obtained an average on the first four units of 62.7%, as compared with 64.2% for Class II and 67.1% for Class III, and on two of these units they exceeded the score of Class II by from 2 to 5 points.

On the Christmas review test, administered immediately after the Christmas holidays, the marks were, Class I - 51.6%, Class II - 61.7%, and Class III - 60%. Here the first class shows an inferiority of 10% as compared with the other two.

In the succeeding five units, Class I shows a consistent inferiority to the other classes, particularly in the more difficult phases of the work. Thus in unit 5, which deals with salt and its compounds and introduces a number of difficult equations and problems, Class I scores low, as also in unit 9, dealing with the compounds of nitrogen. In the

unit on carbon however, Class I showed a surprising superiority over Class II. This unit, as has already been noted in the discussion of it (p.54), is a much easier one than the others, its treatment in Black and Connant's text being very elementary and objective.

On the average, for the nine units of instruction Class I scores 55.6%, Class II scores 58.1% and Class III, 61.4%. This shows a definite inferiority on the part of Class I for the year's work, an inferiority which would have been much more marked but for the exceptionally good results recorded by this class, and noted above, in the case of the unit on carbon.

In the June test class I has the low average of 42%, as compared with 50.0% for Class II and 63.0% for Class III, and in the Fall Review test (1939) this class is again 10 points behind the other two.

It may be a matter of surprise to many that Class I did as well as they did. The amount of direct instruction they received from the teacher must have been less than fifty per cent of what the other classes received, and it may seem incredible to those who are accustomed to assume that there is no learning without the ever-present stimulus of the teacher's voice that this class was able to surpass Class II in four out of nine of the units of the course.

The explanation of this must lie first in the stimulus that a new method of study gives to the student. There was a marked enthusiasm for the work book at the beginning of the year which stood out in sharp contrast to the dilatory habits of Class II. The students of the latter class took several weeks to become accustomed to the methods of the teacher, and offered a good deal of passive resistance to the demand for quiet attentive listening and individual efforts at thinking. Part of this was doubtless due to the fact the situation was one in which a new teacher faced new students. The same situation prevailed, however, in Classes I and III, and in neither of these was this disciplinary problem apparent.

The main defect in the use of a work book seemed to be in the lack of adequate reviews. The work book parallels the text and this goes straight ahead with only the very occasional review exercise occurring at the end of every six or more chapters.

There is little doubt that a correspondence course which does not end in a general examination on the whole course fails to provide adequate training in the subject, for without the final examination there will not be the stimulus to extensive review which is needed to give value to any course.

The same applies to the use of the work book in the class room. With proper amplification on the part of the teacher, and with a full laboratory course, the work book will give average results provided there is a frequent review. It works best, of course, in the hands of students of superior ability. For average or slightly below average students it tends to become mechanical and meaningless with a constant piling up of a debit balance of incomprehension which ultimately results in failure.

Class II.

In this class the customary classroom procedure was followed, and the question arises, is it the most efficient procedure from the point of view of the amount of effort expended.

The general supposition is that the teacher gets out of this system results commensurate with the amount of effort he expends, and yet it is well known among teachers that even when one has exerted to the full all the resources of his knowledge, energy and personality the results are frequently disappointing.

The evidence of this investigation seems to point to the conclusion that the lecture-recitation method generally current in high school teaching is not very efficient, at least, in the teaching of chemistry, and when relied on exclusively is exceedingly wasteful of a teacher's energy.

The main fault with this technique is that it puts too great an emphasis on the teacher-student relationship and underestimates the importance of the student-subject relationship. The teacher usually dominates the scene exclusively. He talks during 50-75% of each class period, and while he usually exhausts himself before the day is over, he generally fails to realize how frequently he exhausts the patience and good nature of his charges, or failing this, how frequently the best behaved and most attentive-looking student may be far away in reverie during these long harangues. Particularly is this so with the modern child who has been only too well trained by the ever-present radio in the art of not paying attention.

There is no doubt that high school teaching suffers a good deal from the culminating effects of a system of education in which the spot-light has been focussed too exclusively on the teacher-student relationship, a relationship which through ten years of schooling tends to be the dominating influence in the student's life without the student being required to play a fully reciprocal part in the process of education.

Reference has already been made to this in the case of Class II during the first two months of the year. Being required to pay attention from the start they were apparently made too much aware of the teacher-student relationship. Their habitual reaction to this situation

was a preoccupation with the disciplinary situation, their interest being focussed on determing what degree of latitude might be tolerated by this particular teacher.

This situation which recurs every year and with every new teacher naturally tends to eclipse the learning situation with consequent bad results. In this class such results were greatly in evidence for the first three units of the course. In Unit 4, however, Class II far surpassed the other two classes. Now this was a difficult unit, involving, as it did, chemical equations and chemical arithmetic, and while their superior results doubtless were in a large measure due to the fact that they had the necessary detailed instruction that the other two classes failed to receive, this could not have had its effect if there had not been a marked improvement in the degree of attention manifested by this class. The opinion of this investigator is that in the lecture-recitation method a class tends to give the minimum of attention necessary to apprehend the general nature of the subject under discussion. If the work is felt to be easy this attention is scant, but if the students realize that a difficult piece of work is on hand the attention generally improves.

This was born out in the case of unit 8 on Carbon. As has already been pointed out the work on carbon was easy and yet this class with the full benefit of the teacher's efforts made the lowest score of the three.

It was because of the high results in unit 4 obtained by Class II, as compared to the other two, that this class was able to register a slightly higher average for the Fall term than even Class III, the marks for which far surpassed those of Class II in every other unit of the course.

In the ultimate test however, namely the June final test, Class II registered a median mark of 51%, which is 9% higher than that obtained by Class I, but 10% behind Class III.

Class III.

Before proceeding to a discussion of the quantitative results obtained in Class III, there are certain observations of a general nature that should be made.

To begin with, this investigation cannot be regarded as having done full justice to the method of instruction advocated by Professor Morrison. As he himself points out, his technique involves for its full development the organization of the whole school. It is impossible to have even a degree of informality of

procedure in a class which has to fit into a school program of definite rigidity. An important feature of the "mastery technique" is that it releases the rapid learners as soon as they have attained mastery and these can then devote themselves to some voluntary project or to attendance in some class where they can work to better advantage. It was found impossible to give the slower workers that extra time and attention which the method demands because, not only was there no room in any other part of the building for those who had completed the unit, there was scarcely room in their own class room for these students to apply themselves to any other task but seat work. This eliminated a valuable incentive to extra diligence. Class room conditions were anything but favorable for the application of the technique. The room was in fact a laboratory and while this was an advantage in conducting a science subject, there was considerable overcrowding and a good deal of discomfort due to the high squeaky stools on which the students sat. One of the essentials that Morrison postulates for the proper application of his method is a 100% control technique. Such conditions as pertained in this class were not conducive to perfect control, although the general tone of the classes was cooperative and industrious.

As to teacher load, Morrison says he has seen his method operating for classes of thirty but postulates

a maximum daily load of 90 - 100 students per teacher. Class III numbered on the average thirty students but the teacher-load totalled for the day nearly 300. When it is said that this involved eight periods of assorted science subjects, each with the possibility of laboratory work, it may well be seen that the full supervision, the testing and retesting, and the individual assessment of each student's progress was a matter far beyond the possibilities of a single teacher.

Another factor which worked against the efficiency of the method was the necessity of keeping Class III parallel with the other two classes in order to compare their results on each test. The Morrison technique is a slower process as far as each unit is concerned although probably the same total content can be covered in a year taking into account the time spent ordinarily on final reviews, a feature which is obviated in Morrison's method. The result of this was that the work in Class III was generally rushed. Study which should have been supervised by the teacher was often assigned for home work, as was most of the written reports and the preparation of oral talks. Another result of this haste was that instead of each student passing every item of the assimilation test, (the ultimate objective in Morrison's "mastery formula"), there was always a percentage of the class which fell short of this. Morrison condemns an 85% achievement

as wholeheartedly as he does the 50% "pass mark", so that in this regard justice was not done to his method.

Finally it must be emphasized again that the basis of comparison for Class III is on the results obtained on their first try at the assimilative test. The test is supposed to be administered to the individual student when the teacher estimates that he is ready for it, that is when he has mastered the unit. As the marks show this was invariably far from the case. The actual situation was that the test was administered to all three classes on the same day, such day being fixed upon for a number of reasons other than the individual student's readiness for it. In spite of this, however, the fact that Class III repeated their study of the unit until most had attained 100% should have resulted and to some extend did, result in superior marks on the final June test.

In view of these many factors it must be admitted that the figures obtained for Class III are only an indication of the relative value of this method. Certain of the limitations listed above apply with equal force to the other techniques, particularly with reference to the over-crowding and poor accommodation, but these more static techniques are better fitted to such conditions.

As to the students' reaction to the method, it was not particularly favorable. There was a good deal of interest evinced at the beginning of the year when the method was explained to the students and they went to work willingly at first. The most enthusiasm was shown for the individual study and experimental work. The repetition of tests was however, regarded as tiresome and the demand for 100% knowledge of the unit was regarded generally as fantastically utopian. The method, of course, involves a re-education of the students in the matter of their whole attitude towards the process of education and such a re-education must begin in the lower grades.

Some good oral talks were given, but the majority of the students did not welcome this innovation in the habitual science routine.

Coming now to a study of the marks obtained by this class we see that in eight of the nine units, (that is, omitting unit 4) the average mark exceeded that obtained by Class I or Class II by at least 6, and in June test, as already stated on page 66, the percentage increment of Class III over Class I is 43, and over Class II, 22.

The efficacy of this technique appears to lie in the presentation of the essential facts and their representation until thoroughly learned by each member

of the class.

Such a method cannot help but produce satisfactory results on the unit test when the latter is administered a week or two later, even though the unit test is supposed to cover a much greater body of knowledge than the bare essentials.

The necessity for complete objectivity in the tests under the Morrison technique makes it inevitable that the essentials will be stressed, so that by concentrating on a few fundamental facts the teacher inevitably prepares the class well for the more inclusive test on the unit as a whole.

The danger here is that the course may degenerate into a study of the highlights of chemistry, with the students failing to build up the body of knowledge which is supposed to be acquired during the assimilative period. It was doubtless a realization of this danger that caused Morrison to stress the point that while an objective test should always be the basis of judgment by which the teacher decides whether the student has attained mastery in the unit, yet ultimately it is a subjective appraisal of the student's orientation which is needed. Furthermore, in the revised edition of his book he advocates the use of ~~a~~ guide-sheets during the assimilative period to make sure the student covers the assimilative material thoroughly.

In this investigation an effort was made to make

the unit tests much more inclusive than the tests which were merely used to determine the effectiveness of the presentation. New items were included to cover points which the student was supposed to have acquired during the period of private study. It was generally the case, however, that these items were the ones not known on the first unit test. The students were sent back to improve their score and then proceeded to study these items. Eventually they knew all the items on the test and they were said to have "mastered" the unit.

Since there were innumberable items in the unit on which they were not tested it would seem that this is somewhat of a travesty on the word "mastery". The fact is that Morrison is somewhat indefinite on this point of "attaining mastery".

When the unit involves some definite principle as in mathematics, the student can be tested each time with a new problem based on this principle. The teacher is then able to judge whether the principle has been mastered. But is such a procedure applicable when the unit involves the acquisition of a body of knowledge? Morrison claims it is, and he justifies this by saying that there is implicit in every real unit of instruction, an adaptation which the student needs to make to his environment. Thus a principle in mathematics is assumed to be equivalent to an environmental adaptation

in science, and the psychological soundness of the general technique advocated by Morrison would seem to stand or fall on the soundness of this assumption. While environmental adaptations are an important part of a scientific education can ~~by~~ they be regarded as the essence of a science course? And if they are, can the success or failure in making this adaptation be judged by a single test or should the items of the test be varied each time the student is examined to determine whethere he has mastered the unit? Morrison does not commit himself on this point and it is the opinion of this investigator that a chemistry course involves a large body of factual knowledge much of which must be learned and which cannot be regarded as merely incidental to some general principle or "environmental adaptation."

If the claims for the Morrison technique are justified the students of Class III should have made a permanent adaptation to their environment in respect to the unit studied at the conclusion of each unit. Not only should their results be better unit by unit, but the cumulative effect should be considerable. Thus, not only should Class III show the increment observed in the June test which was significant, they should also show an equal increment if not a greater one by the end of the summer holidays. For Class III has made a permanent adaptation to their environment whilst Classes I and II are merely subject to the ordinary laws of forgetting

and these are devastating in their effect, apparently, over the summer holidays. The figures for the 1939 Fall review test which was a comprehensive review of the main facts studied during the previous year, give the following:- Class I - 33%, Class II - 41%, and Class III - 39%.

From these we see that while Class III has maintained a superiority over Class I, this superiority is now only 18% as compared to 50% in June and compared to Class II, Class III has actually receded to an inferior position.

In a previous discussion of these figures[1] it was pointed out that the groups tested represented only about one-third of the original classes. For this reason the I.Q.'s of the students tested were also averaged to see if there had been any marked change in their relative abilities. This gave the Class I group an average of 116, whilst Class II and III averaged 106 each. The improvement in the showing of Class I may therefore be attributable to this increase in the average I.Q. As far as Classes II and III are concerned they have been improved equally by selection so that the factor of average I.Q. is ruled out in their cases. The fact that they have equal average I.Q.'s does not mean, of

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[1] Page 70

course, that they are equally good samples of the original classes. Granted all this, the Class III group results are low enough to dispel any certain conviction that this class has maintained, even if it ever acquired it, a marked advantage over Class II.

CHAPTER XIII.

SUMMARY AND SUGGESTIONS.

The following conclusions seem justified from the results of this investigation:-

(1) Any method of study which uses a work book as the main stimulus to study is a relatively poor class room technique.

(2) Even with a good degree of supervision and amplification by the teacher the marks obtained by a class working with work books tend to fall from 10 to 15 per cent below those of other classes.

(3) A correspondence course based on the use of a work book should end with a final examination, otherwise there is not the stimulus to review and without extensive review the work book fails to give adequate instruction.

(4) The lecture-recitation method seems to produce the best results when the material of instruction is more difficult, and is least valuable when the subject matter is elementary relative to the students' general level of advancement.

(5) One of the most valuable features of the lecture-recitation technique is the daily review. On the other hand, lengthy explanations and explicit teaching of every single item of the course are gen-

(5 con't'd.)

erally speaking, uneconomical and fail to bring the expected returns.

(6) In an effort to get the best results possible and to keep the class at maximum efficiency the teacher tends to dominate the scene too completely and to spend too much time teaching. The comparative results of the three classes show that this technique, which is almost exclusively devoted to verbal instruction, does not yield results commensurate with the effort expended.

(7) The Morrison technique gives results which run from 5 to 10 points higher on most of the tests than those obtained in the ordinary type of class room instruction. In the final June test the class taught on the Morrison technique showed a 25% increment over that taught on the customary procedure.

(8) These higher results are probably due to the many repetitions of the work, especially as it applied to the essential facts of the course. There was evidence that the students found this element of repetition rather tiresome.

(9) A test administered to random sections of the classes after a ten weeks' interval failed to endorse Morrison's claim that his technique would give much

(9 con't'd.)
more permanent learning. The forgetting was as great or greater for this class than for the class which had been subject to ordinary teaching methods. This may have been due to the fact that in order to obtain a basis of comparison the Morrison technique was slightly modified in this investigation. It may also have been due to the fact that the groups tested were too small for the results to be regarded as valid.

(10) There was no evidence that because a student had passed every item of an assimilative test that he had "mastered" the unit in Morrison's sense of the word. The normal rate of forgetting operated just as surely in Class III as in the other classes, despite the fact that they were supposed to have obtained something permanent as a result of their method of study.

(11) The application in its entirety of the Morrison method is a slower process than ordinary teaching. In order to cover a full course there is a tendency to rush phases of the work and short cut others. This seriously affects the value of the method since the various steps of the technique need to be well integrated to result in effective teaching.

(12) Despite the reteachings and the frequent repetitions of tests, the system is economical of the

(12 con't'd.)

teacher's energy provided he has adequate mimeographing facilities for the preparation of test blanks. These are essential because tests must be applied to different students at different times.

(13) On the whole, even in its partial application for the purposes of this investigation, the Morrison technique seemed superior to the other two methods, since it was productive of better results with little increase in the demands made on the teacher except such as involved planning and organizational work.

(14) Informality in the laboratory, with students left free to perform experiments whenever they felt the need, was never attained in this investigation. The necessary attitude of detachment in relation to practical work might be attained in students who had received their early instruction on the enterprise method, but it was not sufficiently in evidence in these classes to warrant the use of the method. The formal assignment of laboratory work prevented it from becoming a source of distraction to others who were engaged in study.

(15) The Morrison technique requires a re-education of the student in his attitude towards his work particularly in the matter of the pass-mark. This re-

(15 con't'd.)

education should begin in the lower grades. It is rather late to attempt to change their habits in this regard in Grade XI.

APPENDIX I

JUNE FINAL EXAMINATION IN CHEMISTRY I.

(Taken from the Departmental Examinations for I937, Alberta.)

Answer Question I, and any other seven questions.

Atomic Weights: Fe - 56; H - I; Mn - 55; N - I4;
Cl - 35.5; O - I6; P - 3I; Mg - 24.

I.(a) Numbering the subsections as indicated below, supply only the missing parts.

(I). The chemical substances required to produce calcium cyanamide are............. and ....

(2). .... formulated the Atomic Theory.

(3). The chemical action expressed by Anhydrous copper sulfate + water — blue vitriol, is called ....

(4). The chemical name for washing soda is ....

(5). The solubility of carbon dioxide in water varies .... as the pressure.

(6). The following equation indicates the preparation of nitric acid: .... + ... —.......+ ....

(7). Four products derived from petroleum are ...., ..., ..., and ....

(8). ....+ .... —......... + ... is the equation for the reaction which occurs when hydrogen peroxide is prepared.

(b) Numbering the subsections as indicated below, state in a few words one result which should be observed in each of the following experiments:

(I). A piece of litmus paper (blue) is moistened and dropped into a jar of chlorine.

(2). Hydrogen sulfide is passed into a solution of lead nitrate.

(3). A filter paper soaked in turpentine is dropped into a jar of chlorine.

(4). Solutions of barium chloride and sodium sulfate are mixed.

2. (a) Explain and illustrate each of the following terms:
I.Compound, 2. oxidation, 3. neutralization, 4. dissociation.

(b) Name and state the law which the following experiments illustrate:
I. Ten litres of hydrogen react with 5 litres of oxygen.
2. 2 litres of hydrogen sulfide react with 3 litres of oxygen.

(c) State: I. the law of Conservation of Weight.
2. the law of Definite Proportions.

3. (a).Describe experiments to prove that manganese dioxide acts as a catalyst, when used in the production of oxygen from potassium chlorate.

(b) Describe the technique for cutting and bending glass tubing.

(c) Describe a laboratory test for each of the following:
I. ammonium compounds. 2. Nitrates.

4. Discuss the progress made in the study of burning substances which led to the modern conception of combustion.

5.(a) Describe with the aid of a labelled diagram, an experiment to show that hydrogen may be prepared,dried and used as a reducing agent.
(b) Write equations to indicate each of the chemical reactions which take place in (a).

6. (a) Write the chemical formulae for the following substances: silver carbonate, mercuric nitrite, barium phosphate, aluminum carbide, chlorous acid.

(b) Give the chemical names for the compounds represented by the following formulae: $(NH_4)_2S$, $FeBr_3$, H_3PO_3, $NaClO$.

(c) Calculate the percentage of oxygen in ferrous nitrate, $Fe(NO_3)_2$.

7. (a) A mixture of common salt and sulfuric acid is heated in a generator and the gas produced is dried and passed over hot sodium in a combustion tube.
Write equations for the reactions which take place in the above experiments.

(b) I. How many grams of chlorine are produced by acting on I74 grams of manganese dioxide with hydrochloric acid.

2. How many litres would this chlorine occupy at I7 C and 580 mm. ?

8. (a) Write equations for the chemical reactions which occur in the following experiments:

I. Hydrochloric acid acts on marble chips.
2. Calcium carbide is placed on water.
3. A solution of sodium bisulfite is allowed to drip into sulfuric acid.
4. A mixture of ammonium chloride and sodium nitrite is moistened and heated.

(b) Give one important use for each of the following: chlorine, carbon dioxide, calcium oxide, sodium bicarbonate.

9. (a) Find the simplest formula for the substance whose composition by weight is:

magnesium - 2I.62%
phosphorus- 27.93%
oxygen - 50.45%

(b) Define the term "gram molecular weight".

(c) Describe experiments to identify each of the following gases:
nitric oxide, ammonia, oxygen, nitrous oxide, carbon dioxide.

IO. (a) By referring to sulfur explain what is meant by the term "allotropy".

(b) Show by a labelled diagram only, the apparatus, materials, and method used to prepare and collect a jar of hydrogen sulfide.

(c) Describe how to identify a sulfite.

(d) By means of simple experiments indicate four properties which all acids possess.

APPENDIX II

SAMPLE LESSON FROM WORK BOOK.

CHEMISTRY I

LESSON 4 (a)

Read—Text, Chapter V, Sections 43-49.

Most students will be familiar with the chemical formula for water, viz., H_2O. This tells us that the molecule of water, which is the smallest possible particle of water, is made up of two atoms of hydrogen and one atom of oxygen. The fact that when an electric current is passed through acidulated water we get two parts of hydrogen to one of oxygen would indicate this. When **active metals** such as **sodium,** or **calcium** are dropped into cold water, one half the hydrogen escapes from the water and the metal combines with the oxygen and the rest of the hydrogen to form the **hydroxide** of the metal. **Learn:** Sodium + water → hydrogen + sodium hydroxide.

All acids contain **hydrogen**. When certain metals as **zinc, iron, magnesium** or **aluminum** come in contact with certain of the acids, particularly diluted **sulphuric** and **hydrochloric acid, hydrogen is evolved.** The metal is said to dissolve in the acid. If the residual liquid is allowed to evaporate, crystalline substances known as **salts** are obtained. When sulphuric acid is used, the salts are called the sulphates of the metals, e.g., zinc sulphate (white needle-shaped crystals) or iron sulphate (green crystals). If hydrochloric acid is used the salts are called **chlorides,** e.g., magnesium chloride or aluminum chloride.

The Simple Replacement Series, or as it is sometimes called **The Electro-chemical Series,** is a list of the elements in order of their **activity,** i.e., their tendency to react chemically with other substances, the most active being at the top. **Only those metals above hydrogen displace hydrogen from dilute acids.**

Note the experiments with hydrogen. They illustrate some of the properties of the gas. Note particularly the experiment for obtaining water by burning hydrogen. (Fig. 40).

STUDY QUESTIONS

1. Name two gases which contain hydrogen.

2. How may hydrogen be purified?

3. How may iron be used to separate hydrogen from water?

4. Describe an experiment for obtaining a sample of hydrogen using water and sodium.

5. Compare the activity of the metals calcium and potassium as shown by their reaction with water.

6. Write an equation in words for the reaction between calcium and water.

7. How may sulphuric acid be diluted?

   (N.B.—The acid is poured into the water, never the reverse. Great heat is developed when sulphuric acid is diluted. There is less danger of it spluttering when there is a large volume of water and the acid is added slowly.)

8. Study the laboratory preparation of hydrogen as illustrated in Fig. 36. How does the thistle tube act as a safety device? (Note that the lower end dips below the surface of the acid.)

Is heat required in this reaction?
How is the reaction speeded up?

9. Write a word equation for the reaction that takes place when zinc and hydrochloric acid are used.

10. On what basis are the metals arranged in the simple replacement series?

11. Which of the elements in the list is not a metal?

    Why is it included in the list?

12. What are the particular advantages of a Kipp generator for hydrogen?

13. Describe an experiment that shows that hydrogen burns but does not support combustion.

14. Hydrogen is the lightest of all gases. How may its lightness be demonstrated?

15. Why does a toy balloon filled with hydrogen collapse quickly?

EXAMINATION QUESTIONS

1. Describe with a diagram an experiment that when hydrogen burns, water is formed. Explain fully each part of the apparatus.
2. Complete on your answer paper the following:

   Iron + water →

   Sodium + water →

   Potassium + water →

   Magnesium + sulphuric acid →

   Aluminum + hydrochloric acid →
3. Which of the following are compounds and which are elements?

   Oxygen, water, zinc sulphate, hydrogen, ozone, iron, sodium hydroxide, air, potassium chlorate, mercury oxide. Give reasons in each case.

Write answers also to the following:
Page 58, Nos. 1, 3, 4, 7, 8, 9, 10.

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LESSON 4 (b)

Read—Text, Chapter V, Sections 50-55.

One of the most important properties of hydrogen is its ability to act as a **reducing agent**; i.e., **to extract oxygen from a compound.** Study carefully the experiment to demonstrate this property. (Sec. 51).

The kinetic-molecular theory of gases will be familiar to those who have studied Physics. The main points to remember are:

1. All gases are made up of molecules.
2. There are spaces between the molecules
3. The molecules are in continual motion striking against each other and the containing vessel.
4. This bombardment of the molecules gives rise to pressure in the gas.
5. It also accounts for diffusion.

This theory explains Boyle's Law and the aw of Charles which we studied in Lesson 1 b).

STUDY QUESTIONS

1. Under what conditions is hydrogen an active element?

2. How might you show that a mixture of two parts of hydrogen to one of oxygen, is highly explosive?

3. Explain the use of platinum as a catalyst in the reaction between hydrogen and oxygen.

4. In Fig. 41 what is in the drying tube?

   What is the action of the hydrogen on the copper oxide?

5. How would you make some copper oxide?

6. What evidence is there that the copper oxide has been changed back into metallic copper?

7. Write a word equation for the reaction illustrated in Fig. 41.

8. What are some of the commercial uses for hydrogen?

9. What is meant by the diffusion of a gas?

10. How does the molecular structure of a gas differ from that of a solid or liquid?

11. How does the molecular kinetic theory explain the pressure exerted by a gas?

12. From the point of view of the kinetic-molecular theory explain the action of heat on a gas.

13. What is deuterium?

EXAMINATION QUESTIONS

1. Describe with a diagram an experiment to demonstrate the reducing action of hydrogen. How would you identify the products of the reaction?
2. Describe the construction and use (with hydrogen) of the blast lamp.
3. Make a list of the physical and chemical properties of hydrogen.

Also write answers to the following:

Page 59, Nos. 12, 14, 16, 20, 22, 23, 25.

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